Ground Beetles (Coleoptera: Carabidae) of Eastern Ohio Forests Threatened by the Gypsy Moth, *Lymantria dispar* (L.) (Lepidoptera: Lymantriidae)

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ABSTRACT. **A total of 1,164 individuals representing 49 species of ground beetles was collected by means of barrier-pitfall traps installed in three different forest types (oak, mesophytic, and lowland) at Beaver Creek State Park, Columbiana County, OH, during summer 1990 and spring 1991. The lowland ground beetle community was the most diverse (32 species and 678 individuals) and was dominated by *Pterostichus lucublandus* Lec. and *Harpalus bicolor* F. The oak and mesophytic sites were similar in species richness (23 and 22 species, respectively) and were dominated by *Sphaeroderus lecontei* Dej. and *Dicaelus politus* Dej. Pheromone trapping in 1990 revealed only 96 adult male gypsy moths with numbers greatest in the oak and lowland sites. Species of ground beetles present at Beaver Creek State Park and known to attack gypsy moths in Pennsylvania include *Sphaeroderus canadensis* Chd., *Pterostichus adoxus* Say, *P. lucublandus* Lec., *P. stygicus* Say, and *Chlaenius emarginatus* Say.**

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INTRODUCTION

Ground beetles are a large family of Coleoptera which are found in a wide range of terrestrial habitats including forests and woodlands. Some forest carabids are arboreal and search for prey in trees; however, most occur on or near the ground. Carabids are not directly associated with particular plant species but are often found on soils typical of different forest types and topography (Ball 1980, Thiele 1977). Soil texture and moisture are critical for most forest-dwelling species and many occur under dense vegetation, logs, stones, or along woodland streams (Lindroth 1969b). Adults and larvae of most ground beetle species are generalized predators of insects and other invertebrates; however, many species feed as herbivores, omnivores or scavengers (Allen 1979). Species that attack important agricultural and forest insect pests such as the gypsy moth, *Lymantria dispar* (L.), are considered to be beneficial (Reeves et al. 1983, Thiele 1977, Tostowaryk 1972). Recent studies by Cameron and Reeves (1990) utilizing the enzyme-linked immunosorbant assay (ELISA) (Vanderkooi 1984) to test for the presence of gypsy moth proteins in the guts of adult carabids have shown that more than 30 species of ground beetles in southwestern Pennsylvania either prey upon or scavenge gypsy moth larvae and pupae.

Since the use of DDT and other chlorinated hydrocarbons was discontinued in the early 1970s, the gypsy moth has spread throughout Pennsylvania and has been reported in Michigan, Ohio, and several southern states (Dreistadt and Weber 1989). Because gypsy moth populations are rapidly increasing throughout eastern Ohio (Ohio Department of Agriculture 1991), large scale control programs may be undertaken in the near future to combat this insect which has defoliated hundreds of millions of acres throughout the northeast (Dreistadt and Weber 1989). Defoliation by gypsy moth larvae is often severe in upland oak forests (Doane and McManus 1981); thus the impact of the insect is expected to be greatest in unglaciated southeastern Ohio where oaks are the major species in upland and ridge-top forests. Dreistadt and Weber (1989) reviewed the life history, damage, ecology, and control of the gypsy moth in the states of the Northeast and Great Lakes regions. As the use of chemical insecticides and insect growth inhibitors kills non-target organisms including birds and beneficial insects, entomologists are evaluating the role of insect parasitoids and predators such as ground beetles and spiders in controlling or slowing the spread of the moth (Cameron and Reeves 1990; Weseloh 1985a,b).

The objectives of the present research were: 1) to survey the ground beetles (Carabidae) of the three major forest types (upland oak, mixed mesophytic, and lowland) of a representative region of unglaciated Ohio; 2) to evaluate the ground beetle fauna of eastern Ohio forests as natural control agents of the gypsy moth based on published results of other studies; 3) to provide baseline data to evaluate the responses of ground beetles to increasing gypsy moth populations in eastern Ohio forests; and 4) to estimate the size of the gypsy moth population of the upland mixed oak, mixed mesophytic, and lowland forests of Beaver Creek State Park at the time of the survey.

MATERIALS AND METHODS

Three study areas (Fig. 1) located in the Beaver Creek State Park, Columbiana County, OH, were chosen for their conformity to Ohio's hill country forest types—lowland, mixed mesophytic, and upland mixed oak (King 1979). Although each area differed in general topography, they shared a common geologic history of the Little Beaver Creek watershed just south of the terminal moraines of glaciated eastern Ohio. Soils all belonged to the Dekalb-Weikert-Allegheny Association. Also, the number of male gypsy moths reported from Columbiana County by the Ohio Department of Agriculture (1991) represented a rapidly increasing population that may in the near future result in significant defoliation.

The lowland forest site was located on the northern flood plain of Little Beaver Creek east of Sprucevale near Hambleton's Mill. Its alluvial soils are of medium acidity

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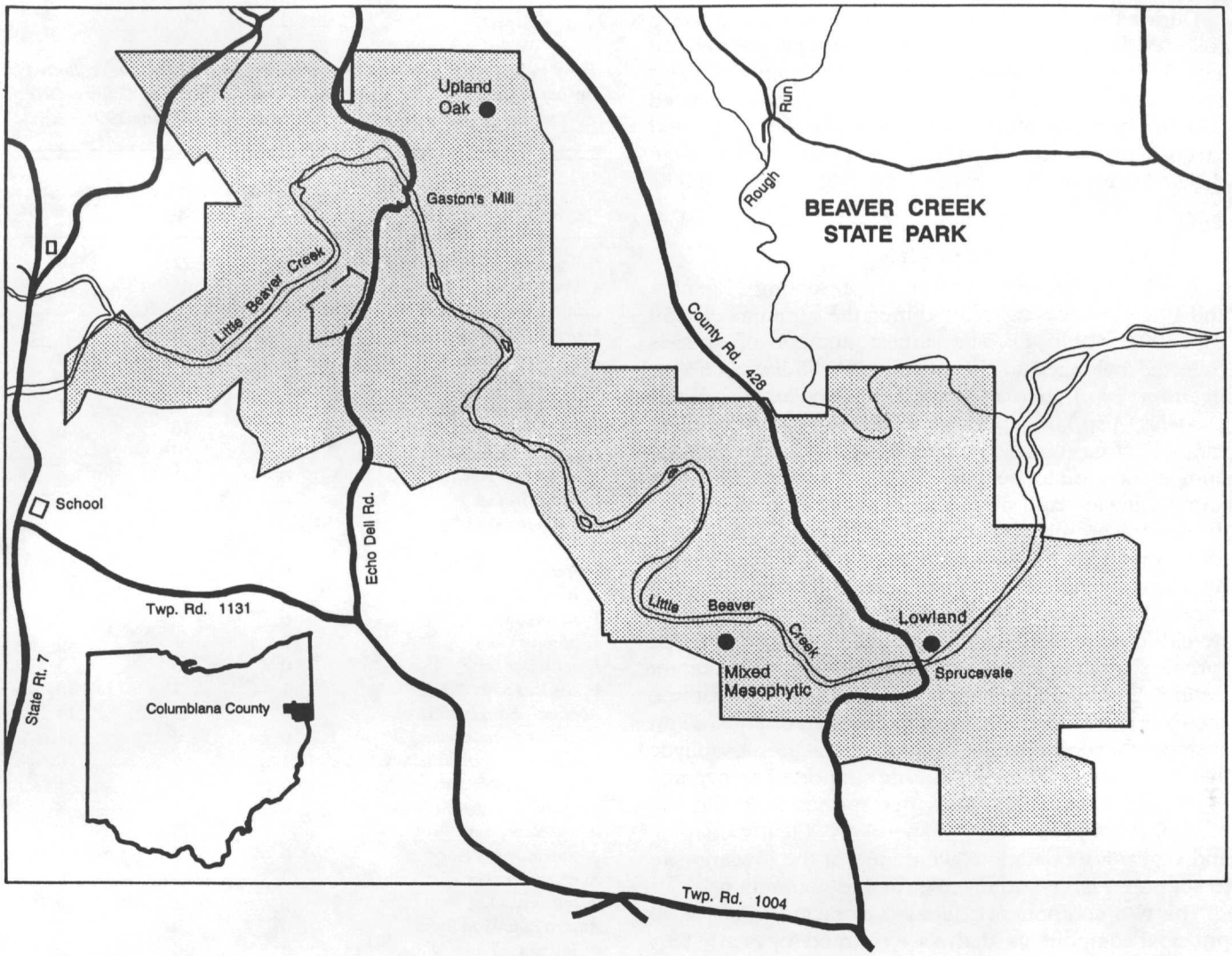

FIGURE 1. Three ground beetle collection sites (upland oak, mixed mesophytic, and lowland forest types) located in Beaver Creek State Park, Columbiana County, OH.

and have been characterized as Chagrin loam (Lessig et al. 1968). The dominant vegetation was honey locust (*Gleditsia triacanthos* L.) and eastern sycamore (*Platanus occidentalis* L.).

The mixed mesophytic forest site was on a north-facing, 30-40% slope south of Little Beaver Creek, approximately 0.5 km west of County Road 428. This site with its Dekalb stony loam soils was dominated by sugar maple (*Acer saccharum* Marsh), white ash (*Fraxinus americana* L.), and black cherry (*Prunus serotina* Ehrh.).

The upland mixed oak forest site was located on a south-facing ridge north of the Vondergreen trailhead near Gaston's Mill and the park office. The shallow, well-drained Weikert and Muskingum soils supported primarily chestnut oak (*Quercus prinus* L.) and white oak (*Quercus alba* L.) and, on lower, steeper slopes, hemlock (*Tsuga canadensis* [L.] Carr.). Both mesophytic and oak sites had moderate accumulations of organic matter with a thin humus soil layer.

In each study area, five barrier-pitfall traps were placed 10-15 m apart to inventory the ground-inhabiting carabids. Precise positioning and orientation of each trap was dependent on site topography and obstacles such as trees, roots, or rocks. Each pitfall trap consisted of two plastic cups (17 cm diameter) dug into soil to a depth of about 18 cm and filled with 150 ml of 10% formalin as preservative. A Plexiglas™ barrier (20 x 90 cm) placed between the two traps intercepted beetles moving through the leaf litter, increasing the number of carabids collected (Reeves 1980, Reeves et al. 1983). Traps were emptied and recharged approximately every 10 days between 13 June and 18 September 1990, and 10 May and 2 June 1991, for a total of 13 collections. Each collection-sample consisted of the organisms caught in each end of the barrier-pitfall trap. Samples were transferred to small plastic cups and transported to the laboratory where specimens were removed, washed in 80% ethanol, and mounted on insect pins. Specimens were identified to species by keys presented in Lindroth (1961, 1963, 1966, 1968, 1969a,b). Untransformed and transformed log $(n + 1)$ data were subjected to an analysis of variance (alpha = 0.05) for the 18 most common carabid species and the sites x species matrix to a principal components analysis using the computer program StatView 512+.

During the summer of 1990, gypsy moth males were collected by the use of 16.5 cm delta-type pheromone traps. Two traps were placed in each forest type approximately 1.5 m above the ground nailed to the trunk or suspended from branches of saplings in proximity to pitfall traps 1 and 5 (separating the pheromone traps by 45-60 m). Traps were checked every 10 days from 6 July to 20 August 1990.

RESULTS

A total of 1,164 ground beetles representing 24 genera and 49 species was collected during the summers of 1990 and 1991 (Table 1). The largest number of species collected belonged to the genera *Pterostichus* (12 sp.), *Agonum* (5 sp.), *Amara* (3 sp.), *Anisodactylus* (3 sp.), and *Dicaelus* (3 sp.). All species were typical forest-dwelling carabids of eastern deciduous woodlands. The greatest number of ground beetles (678) and species (32) was found at the lowland site (Table 1) where more than twice the number present at the mesophytic site (315) and nearly four times that of the oak site (171) were collected. Although an analysis of variance of the 18 most common carabid species (10 or more total specimens) revealed no significant differences among the three forest sites (F = 1.82, P = 0.18), some important distinctions should be noted. A comparison of the three sites based on the 18 most common carabids showed an average of seven more beetles per species at the mesophytic than the oak site. The lowland site supported an average of 19 and 26 more carabids per species than did the mesophytic and oak sites, respectively. Clearly edaphic and vegetation conditions were ideal at the lowland site to support a large and diverse carabid community.

The two components (factors) extracted in a 3 x 49 principal components analysis accounted for nearly 93% of the variation in carabid abundance and expressed species differences between the lowland and upland (oak and mesophytic) carabid beetle communities. Plotting the factor coefficients as a two-dimensional ordination (Fig. 2) showed a great dissimilarity between the ground beetle community of the lowland site and those of the oak and mesophytic sites. The main reason why the lowland site was so dissimilar to the other two resulted from the large numbers of *Anisodactylus agricola* Say, *Harpalus bicolor* F., *Pterostichus fatuus* Lec., *P. lecontelanus* Ltsh. and *P. lucublandus* Lec. which were either absent from or present in small numbers at the oak and mesophytic sites (Table 1). Of the 12 *Pterostichus* species, only four did not occur at the lowland site. Of these only one, *P. adoxus* Say, was fairly common at the upland sites. *Sphaeroderus canadensis* Chd., *S. lecontei* Dej., *Dicaelus politus* Dej., and *D. teter* Bnlli., which were found at both upland sites, were virtually absent from the lowland site.

Since only 14 species of ground beetles occurred at both the Ohio and Pennsylvania sites, the low similarity between these sites was not surprising (Sorensen's community coefficient S = 0.33). One reason for the dissimilarity between the sites was that 14 more species were collected in the present study than were reported from Somerset County, PA, possibly the result of sampling three different forest communities. A number of species that were present in Pennsylvania and that also showed a moderate to high response to gypsy moth (% ELISA test) were either absent or rare at the Beaver Creek sites. These included *Calosoma frigidum* Kby., *Carabus limbatus*

TABLE 1

Forty-nine species of ground beetles (Coleoptera: Carabidae) collected by pitfall traps at Beaver Creek State Park, Columbiana County, OH, 13 June - 18 September 1990 and 10 May - 2 June 1991.

Species	Number collected and forest type		
	Oak	Mesophytic	Lowland
Sphaeroderus canadensis Chd.	7	22	0
S. lecontei Dej.	36	51	16
Carabus limbatus Say	5	0	0
Scarites subterrameus F.	0	0	1
Myas coracinus Say	20	0	0
Patrobus longicornis Say	0	0	1
Bembidion quadrimaculatum L.	0	0	1
Pterostichus adoxus Say	15	16	0
P. caudicalis Say	0	0	1
P. coracinus Newmn.	0	1	0
P. corvinus Dej.	0	0	2
P. honestus Say	0	2	1
P. fatuus Lec.	0	0	59
P. lecontelanus Ltsh.	0	0	25
P. lucublandus Lec.	3	1	249
P. mutus Say	6	0	0
P. obionis Csiki	0	1	0
P. scrutator Lec.	0	0	3
P. stygicus Say	1	7	18
Abacidus hamiltoni Horn	0	1	14
Calathus opaculus Say	0	0	1
Synuchus impunctatus Say	1	0	0
Olisthopus parmatus Say	0	1	1
Agonum dilutipenne Mtsky.	0	1	8
A. hypolithos Say	1	0	1
A. melanarium Dej.	0	0	1
A. opaculum Lec.	1	0	0
A. tenuicolle Lec.	0	1	0
Amara cuprelata Ptys.	0	0	14
A. impuncticollis Say	0	0	2
A. pennsylvanica Hwd.	0	0	18
Harpalus bicolor F.	1	1	124
H. fulgens Csiki	0	0	2
Trichotichnus vulpeculus Say	2	8	0
Stenolophus ochropezus Say	0	0	1
S. rotundicollis Hman.	0	0	1
Anisodactylys agricola Say	1	15	59
A. interstitialis Say	0	0	16
A. lugubris Dej.	0	0	1
Dicaelus elongatus Bnlli.	0	1	0
D. politus Dej.	35	112	1
D. teter Bnlli.	13	12	0
Chlaenius emarginatus Say	2	40	10
Cymindus americana Dej.	3	0	0
C. neglecta Hman.	1	0	0
Anisotarsus terminatus Say	13	13	24
Pinacodera platicollus Say	1	0	0
Apenes lucidula Dej.	1	7	0
Galerita bicolor Dry.	2	1	2
Site Totals	171	315	678
Species/Site	23	22	32

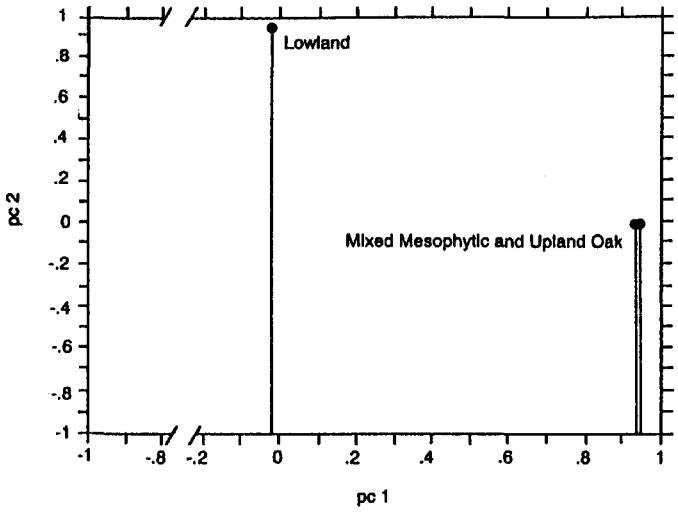

FIGURE 2. Principal components ordination of upland oak, mixed mesophytic, and lowland ground beetle communities, Beaver Creek State Park, Columbiana County, OH.

TABLE 2

Number of adult male gypsy moths collected by pheromone traps from 6 July to 20 August 1990 at upland oak, mixed mesophytic, and lowland forest sites, Beaver Creek State Park, Columbiana County, OH.

	Number of male gypsy moths					
	Oak		Mesophytic		Lowland	
	Trap No.		Trap No.		Trap No.	
Date	1	2	1	2	1	2
13 July	1	10	1	0	3	5
19 July	5	4	5	8	8	7
8 August	9	7	3	5	10	4
18 August	0	0	0	0	1	0
Trap Totals	15	21	9	13	22	16
Site Totals	36		22		38	

Say, *C. wilcoxi* Lec., *Myas cyanescens* Dej., *Platynus (Agonum) decentis* (Say), *Pterostichus hypolithus* (Say), *P. coracinus* Newm., *P. lacrymosus* Newm., *P. rostratus* (Newmn.), *P. mutus* Say, *P. pennsylvanicus* Lec., and *Synuchus impunctatus* Say. Species that were abundant at Beaver Creek (20 or more individuals) but not Somerset County, PA, were *Anisodactylus agricola*, *Anisotarsus terminatus* Say, *D. politus*, *H. bicolor*, *Pterostichus fatuus*, *P. lecontelanus*, *P. lucublandus*, and *S. lecontei*.

A total of 96 male gypsy moths was collected at the three sites (Table 2). The greatest numbers of moths were present at the oak and lowland sites (36 and 38, respectively) and the fewest at the mesophytic site (22). Only two male moths were collected in 1991 since pheromone traps were not available until after 1 August.

DISCUSSION

Results of pheromone trapping by the Ohio Department of Agriculture (1988, 1991) show that the gypsy moth has increased dramatically in eastern Columbiana County in the past four years; however, no defoliation has been reported. Based on our 1990 pheromone trap data, the moth was uncommon at the Beaver Creek State Park forest sites sampled for carabid beetles. These results indicated that populations will be highest in upland oak and lowland forests and lowest in mixed mesophytic forests, a trend that has been observed throughout much of the insect's range (Doane and McManus 1981).

Based on the percentage of individuals shown to prey on or scavenge larvae and/or pupae in Pennsylvania, the following species could be important natural enemies of gypsy moths in Ohio forests. *Sphaeroderus canadensis* was most abundant in the mixed mesophytic forest site and 35% of the Pennsylvania population tested positive for gypsy moth antigen by ELISA. Sixty-two percent of a small Pennsylvania population of *Pterostichus adoxus* tested positive and was equally abundant in Ohio mixed mesophytic and upland oak woods. *Pterostichus lucublandus* was very abundant at the lowland site, rare at the oak site, and absent from the mesophytic site. Forty percent of a small southwestern Pennsylvania population of this species tested positive for gypsy moth antigen. *Pterostichus stygicus* was found only at the lowland site and showed a modest (27%) response to gypsy moth prey in Pennsylvania. *Dicaelus politus* was collected at all three Ohio sites, but was common only at the upland oak and mesophytic sites. One fifth of the Pennsylvania population attacked gypsy moths. *Chlaenius emarginatus* occurred at all three sites but was most common at the mesophytic site. As the only specimen collected in Somerset County tested positive, it is difficult to predict the importance of this species in Ohio.

Numerous attempts have been made to introduce parasitoids into North America in the past one hundred years to control the gypsy moth. However, only ten parasitoid and two predator species have become established (Doane and McManus 1981, Dreistadt and Weber 1989) and have generally been ineffective in preventing gypsy moth outbreaks. The ground beetle *Calosoma sycophanta* L. was introduced from Europe in the early 20th century and has spread throughout much of the northeast (Doane and McManus 1981, Weseloh 1985a). Adults and larvae of this large ground beetle, together with other native carabids such as *Calosoma caladium* (F.), *C. frigidum* and *C. scrutator*, actively search for and attack gypsy moth larvae and pupae. Populations of these predators can increase dramatically during outbreaks and take large numbers of gypsy moth pupae present on tree trunks (Weseloh 1985a,b). The most important natural control agents have been small mammals (Campbell and Sloan 1976, 1977), *Bacillus thuringiensis* (Doane and McManus 1981, Dreistadt and Weber 1989), and the fungus *Entomophaga maimaiga*, which was first introduced in 1910. The fungus causes exceptionally high larval mortality during wet springs resulting in dramatic population crashes of the moth (Schultz 1991).

While the role of introduced parasitoids in controlling gypsy moth populations is poorly understood, even less

is known about the importance of insect predators in this regard. Where the moth has been established for several years (e.g., southwestern Pennsylvania) many species of ground beetles attack one or more life stages of the insect (Cameron and Reeves 1990). In general, the impact of insect predators and parasitoids is thought to be greatest during the decline phase of gypsy moth outbreaks (Weseloh 1985a). However, the importance of ground beetles and other natural enemies may be greatly underrated, especially when gypsy moth populations are low. Discounting their importance may result from the nocturnal feeding activities of most carabids when they are least likely to be observed.

The low degree of similarity between the carabid faunas of Somerset County, PA, where populations of gypsy moth have prompted control measures (Cameron and Reeves 1990) and Columbiana County, OH, where the moth has only recently invaded, does not necessarily mean that ground beetles will be of minor importance in slowing the increase in gypsy moth populations in eastern Ohio. Populations of the 13 species reported from both Somerset County, PA, and Columbiana County, OH, which are known to attack the gypsy moth may increase dramatically if yearly populations of the moth continue to double throughout eastern Ohio. The absence of arboreal *Calosoma* species from the Beaver Creek sites may have resulted from the lack of tree trunk barrier traps (Cameron and Reeves 1990, Weseloh 1985a) in this study, or from the low gypsy moth population at the time of the survey. Weseloh (1985a) found that populations of *C. sycophanta* were highest during the second or third year of a gypsy moth outbreak. Species of *Calosoma*, if not already present, will likely invade eastern Ohio forests as populations of their prey increase. It is hoped that this study will provide baseline data to evaluate the response of ground beetles as the gypsy moth becomes more abundant throughout eastern Ohio.

Of course, populations of carabid species absent from or uncommon in eastern Ohio may increase dramatically as gypsy moth populations increase. Species present at only one or two forest types in Ohio may invade different forest communities in response to high gypsy moth populations. However, restriction to a particular soil type and its microclimate could prevent some species from becoming established in different forest types. Future monitoring of the carabid populations of Beaver Creek State Park should allow us to better evaluate the impact of ground beetles on gypsy moth populations of eastern Ohio forests.

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